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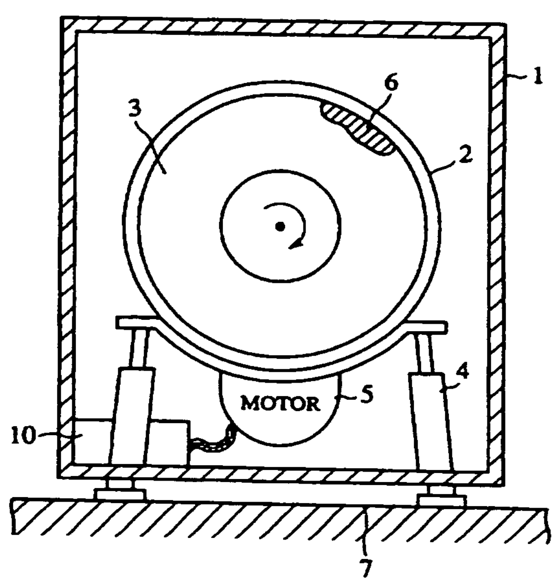
WPI

(54) Abstract Title
Control of spin-drying phase of washing machine

(57) A front-loading washing machine has a control circuit (10) that increases, in a spin-drying operation, the revolution speed of a washing-and-spin-drying drum in steps up to a predetermined spin-drying speed (NO), in which the steps include one whose revolution speed (N2) is lower than that (N1) of the preceding step. The speeds (N1) and (N2) can be based on the quantity or the quality of the laundry by using the load torque on the drum motor. The control means may be cycled through speeds (N1) and (N2) several times to remove an unbalance. If the unbalance cannot be removed the speed (N1) and (N2) are increased and the spin-drying speed (N0) decreased.

FIG.1



GB 2 322 141 A

FIG.1

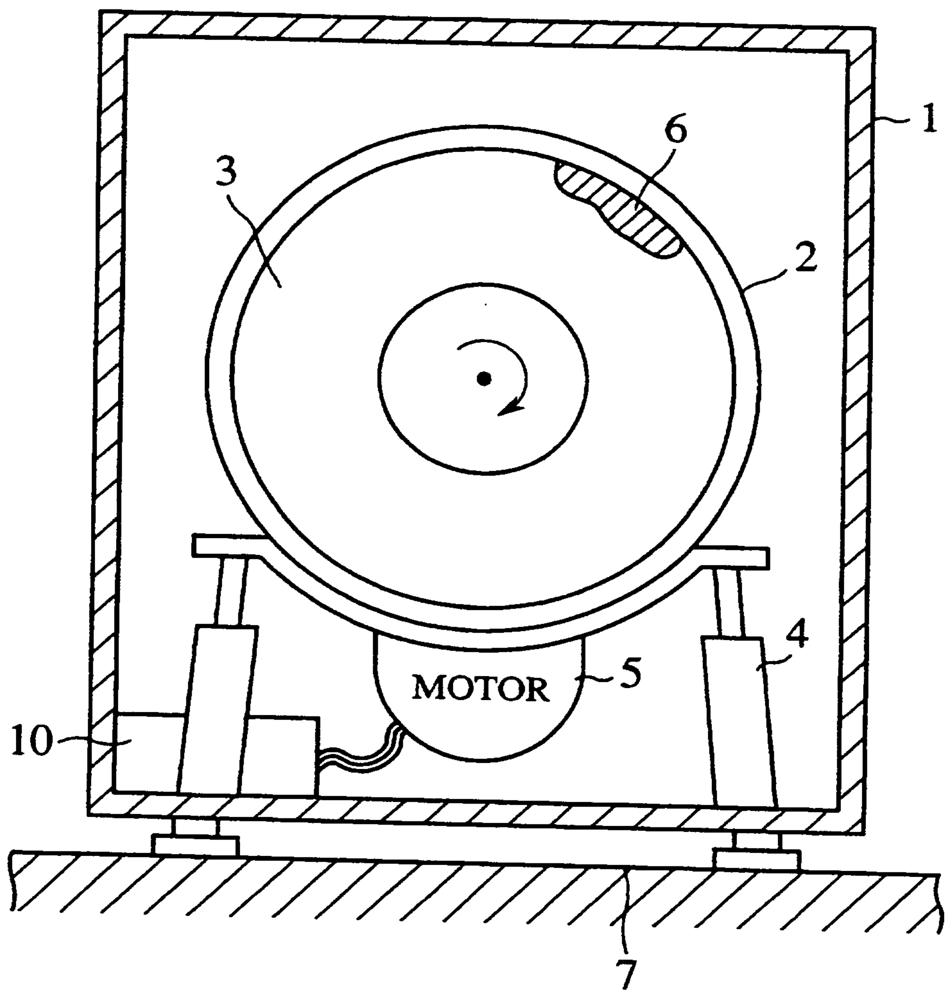
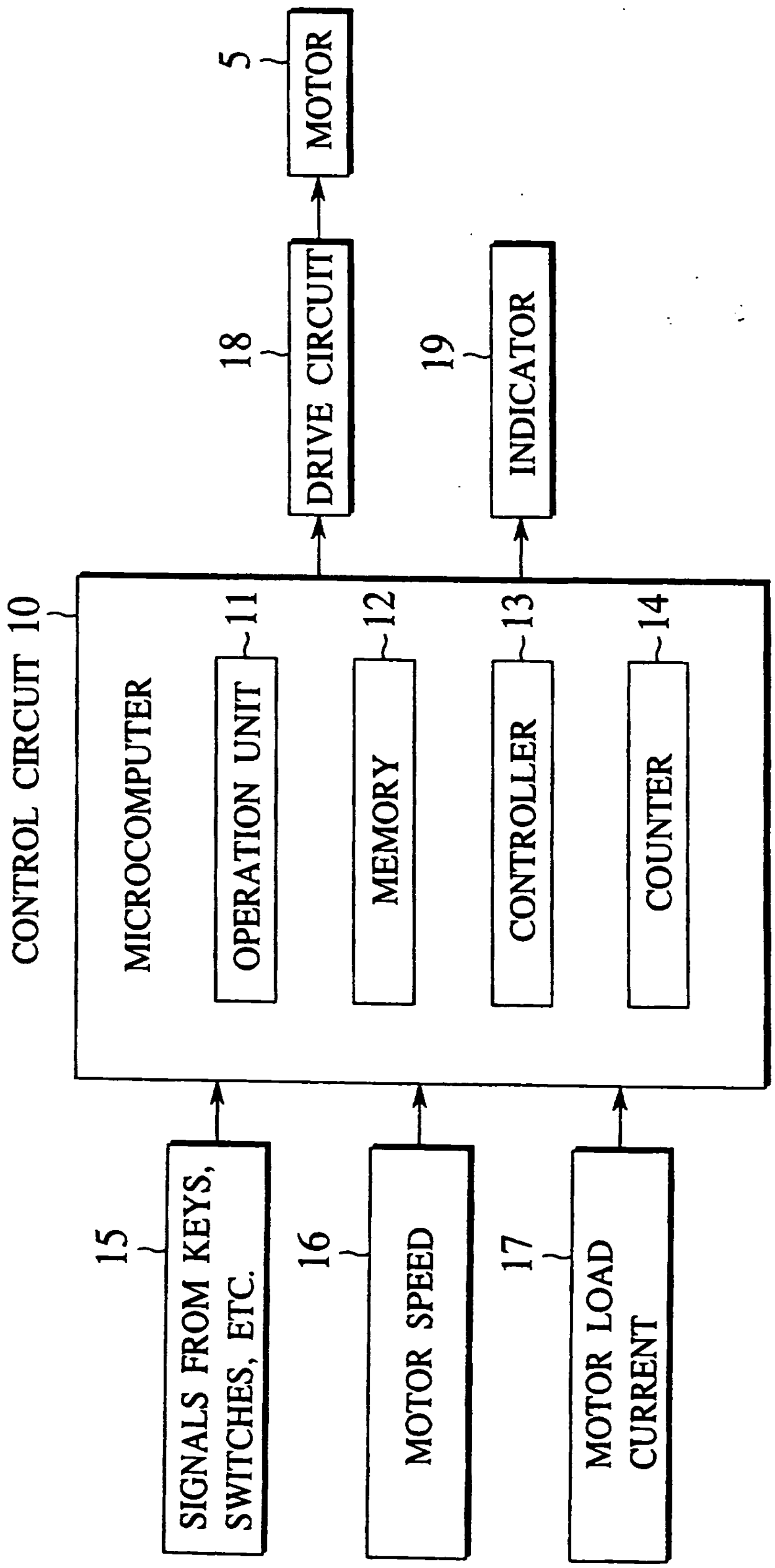


FIG.2



CONTROL CIRCUIT 10
MICROCOMPUTER
OPERATION UNIT
11
MEMORY
12
CONTROLLER
13
COUNTER
14
DRIVE CIRCUIT
18
MOTOR
5
INDICATOR
19
SIGNALS FROM KEYS, SWITCHES, ETC.
15
MOTOR SPEED
16
MOTOR LOAD CURRENT
17

FIG.3

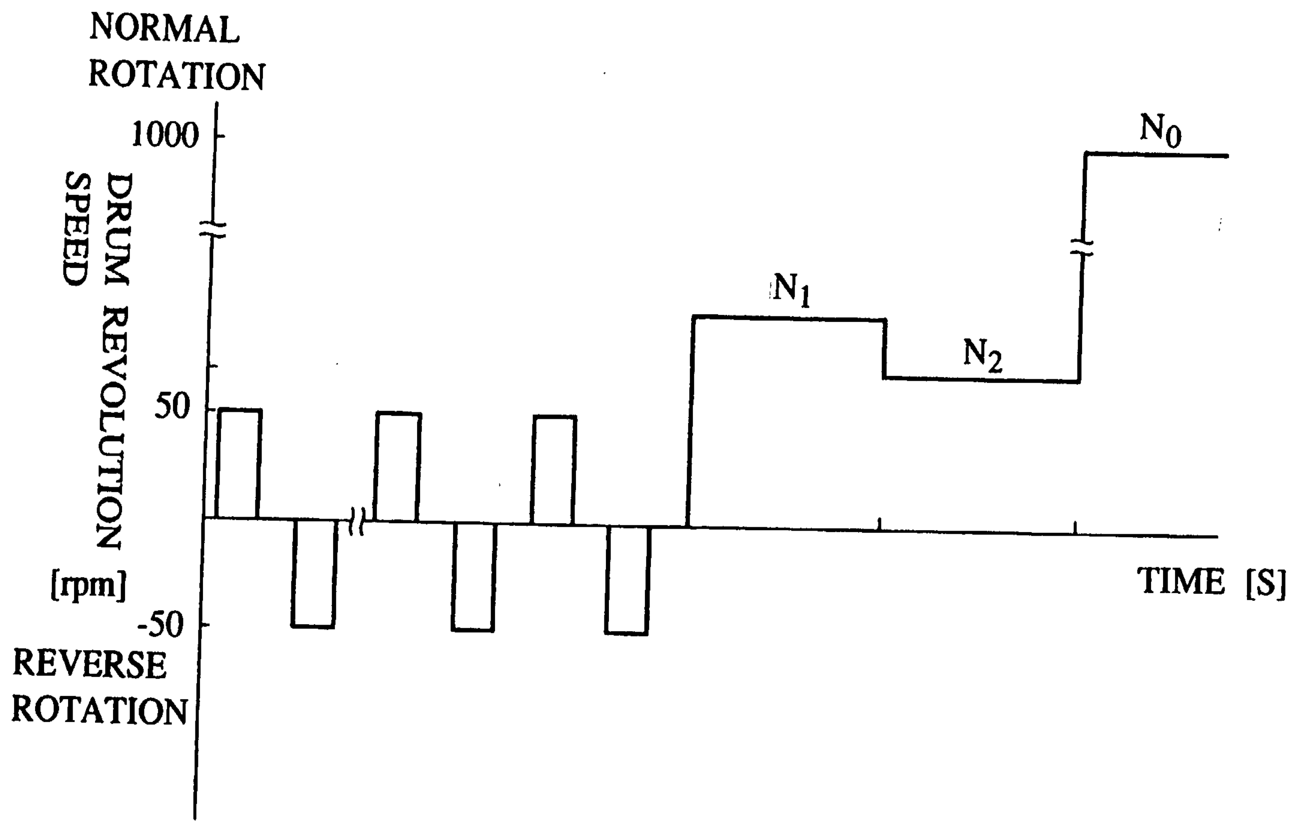

NORMAL
ROTATION
1000
50
-50
DRUM REVOLUTION
SPEED
[rpm]
REVERSE
ROTATION
N1
N2
N0
TIME [S]

FIG.4A

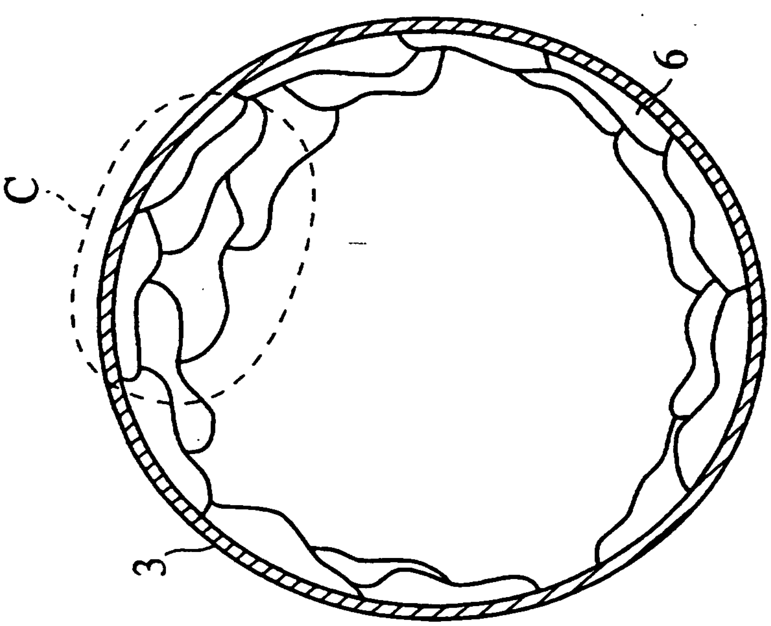


FIG.4B

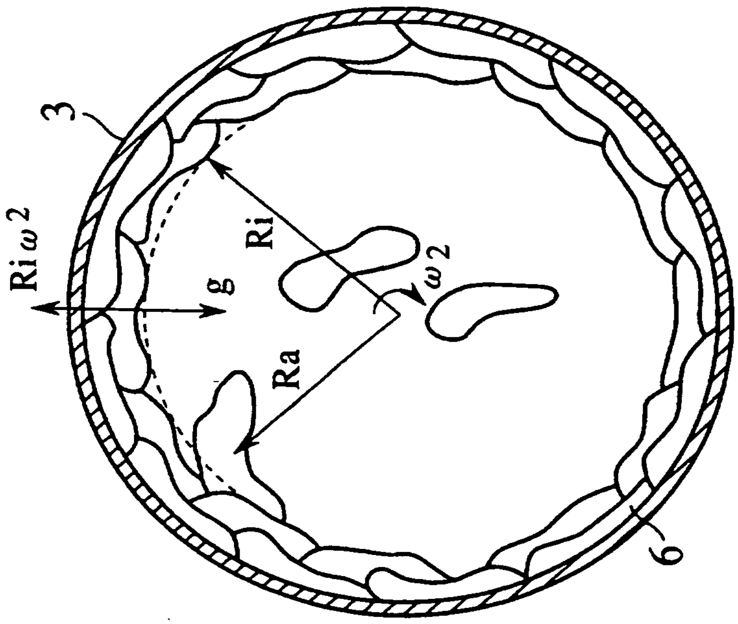
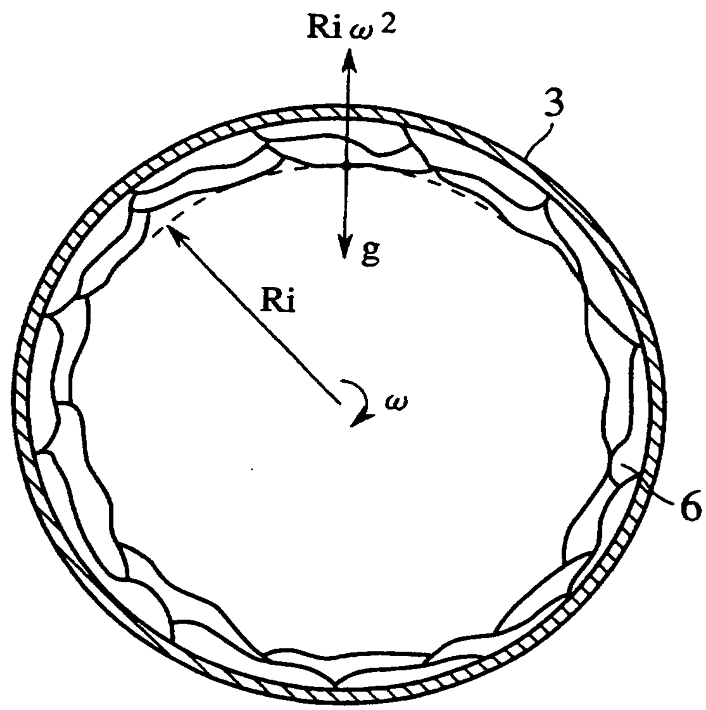


FIG.5



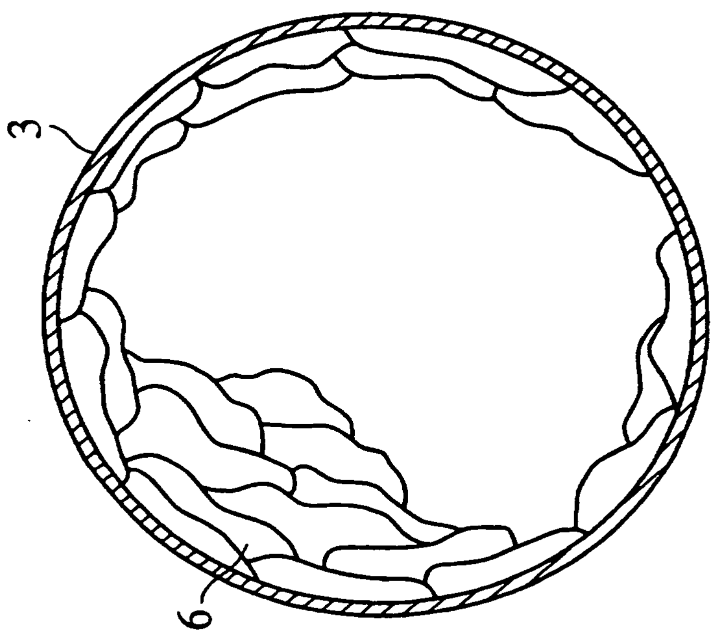


FIG.6A

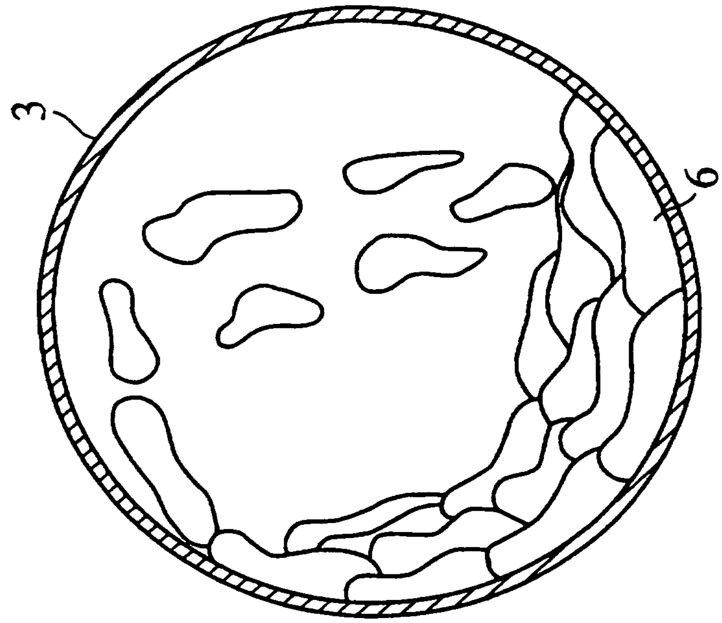


FIG.6B

FIG.7

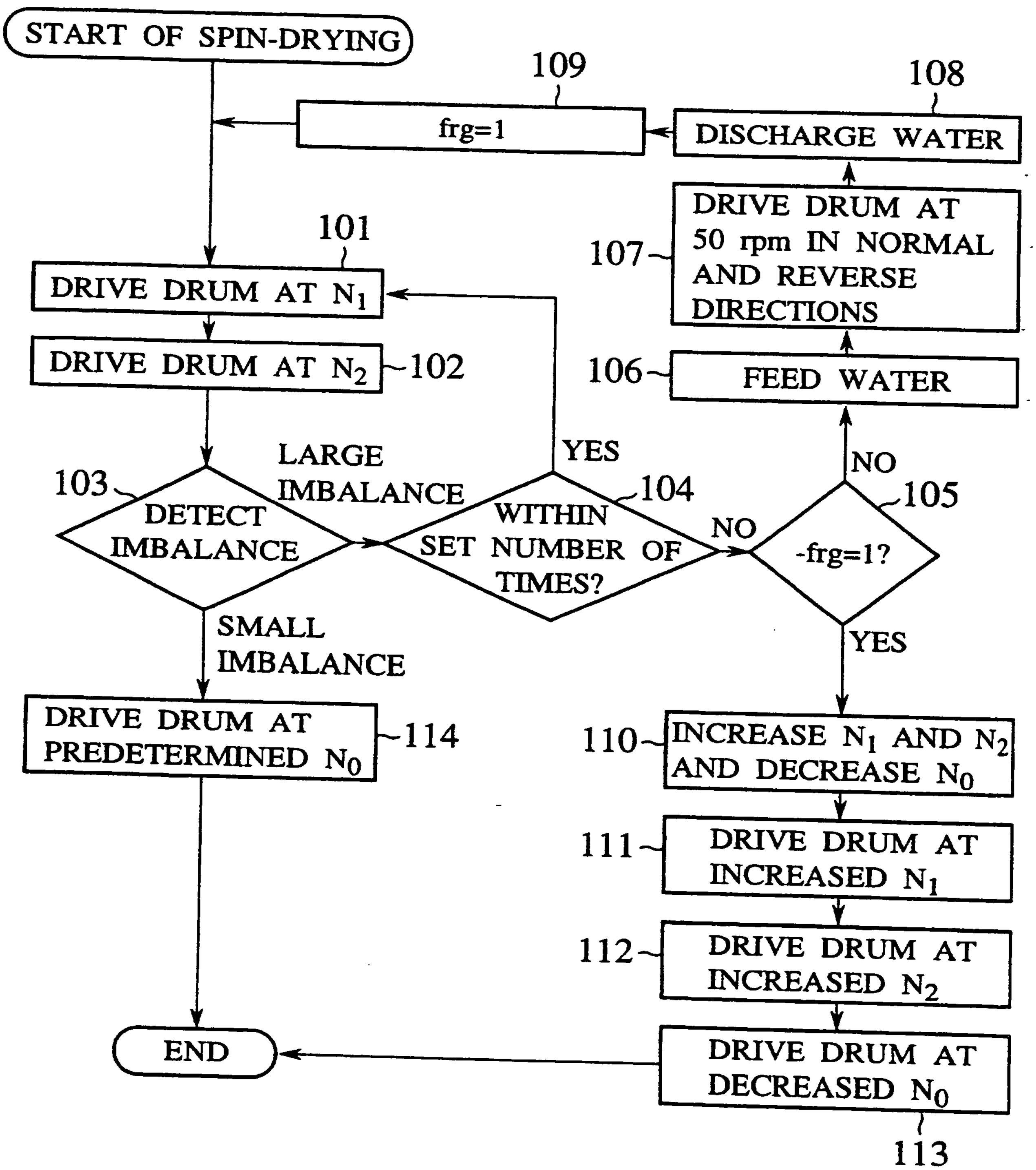

START OF SPIN-DRYING
109
frg=1
108
DISCHARGE WATER
101
DRIVE DRUM AT N_1
107
DRIVE DRUM AT 50 rpm IN NORMAL AND REVERSE DIRECTIONS
DRIVE DRUM AT N_2
102
106
FEED WATER
LARGE IMBALANCE
YES
NO
103
DETECT IMBALANCE
104
WITHIN SET NUMBER OF TIMES?
NO
105
-frg=1?
SMALL IMBALANCE
YES
DRIVE DRUM AT PREDETERMINED N_0
114
110
INCREASE N_1 AND N_2 AND DECREASE N_0
111
DRIVE DRUM AT INCREASED N_1
112
DRIVE DRUM AT INCREASED N_2
END
DRIVE DRUM AT DECREASED N_0
113

FIG.8
PRIOR ART

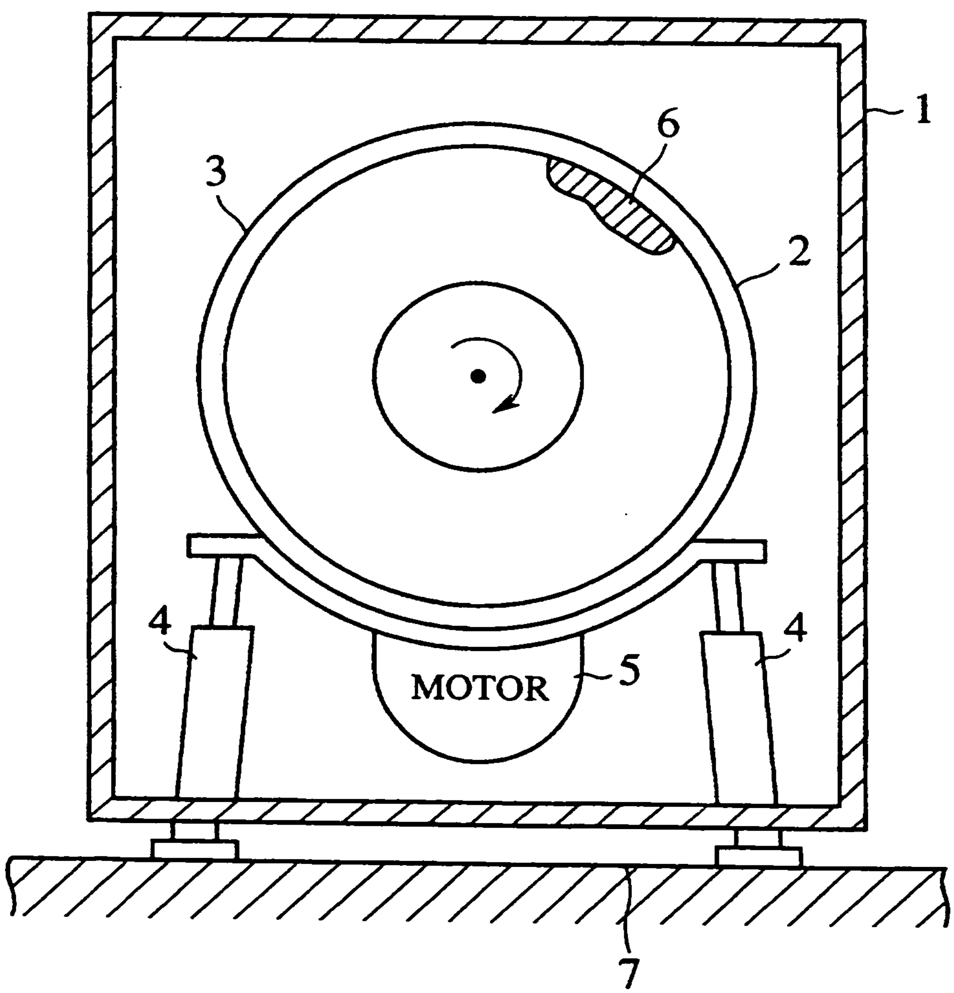


FIG.9
PRIOR ART

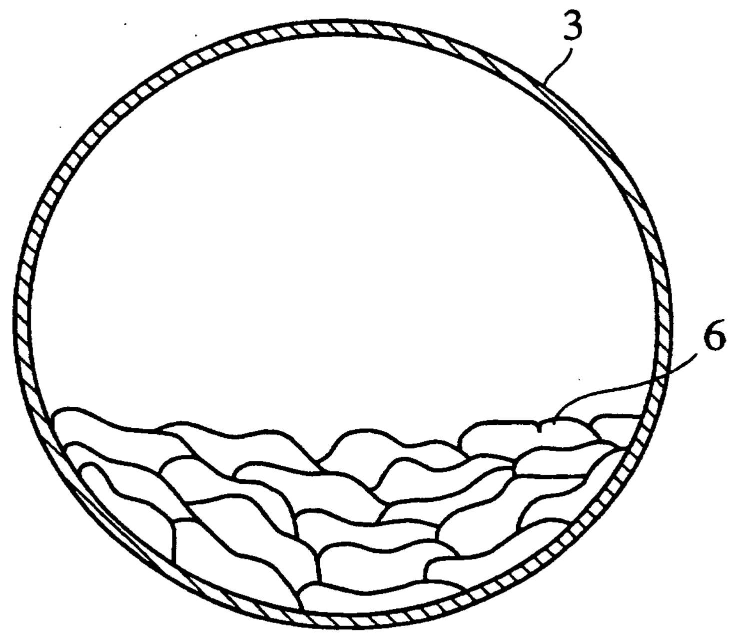


FIG.10
PRIOR ART

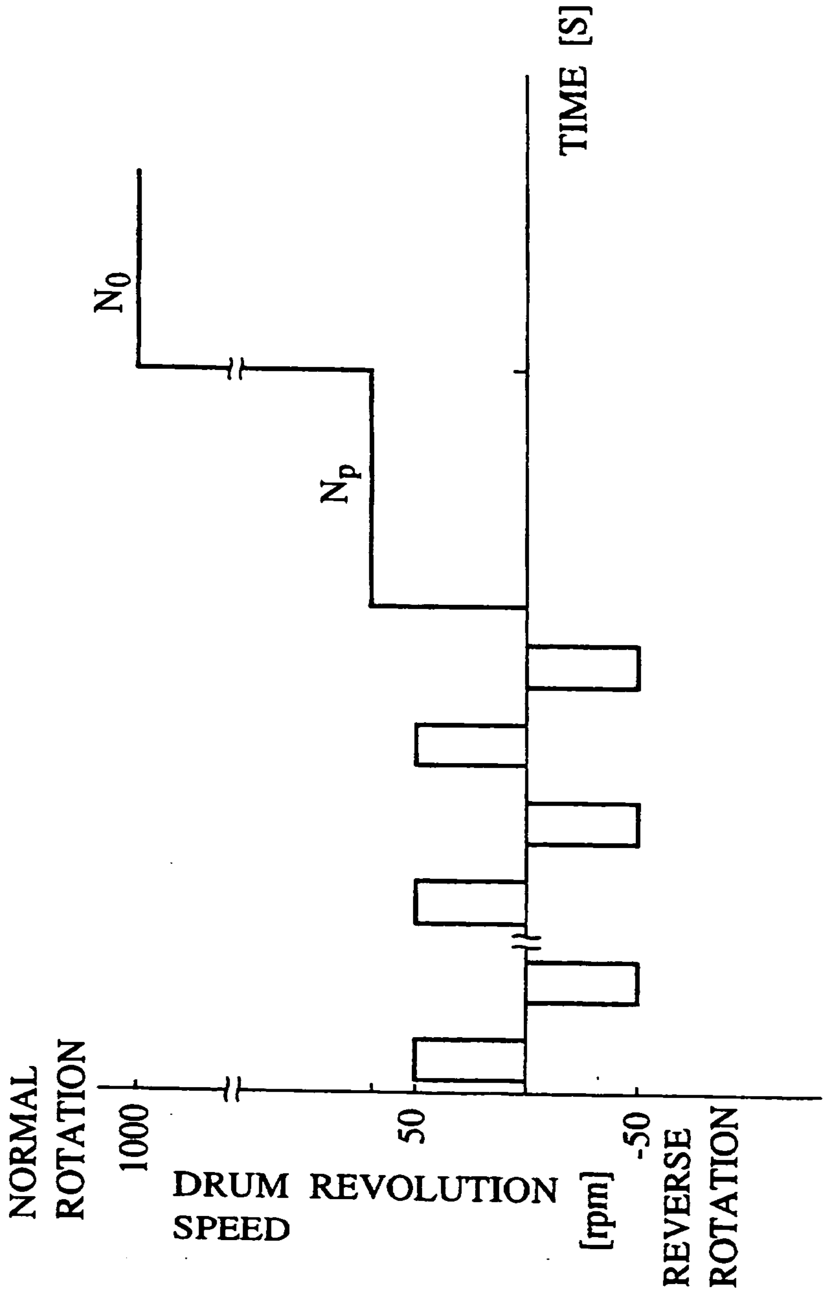


FIG.11A
PRIOR ART

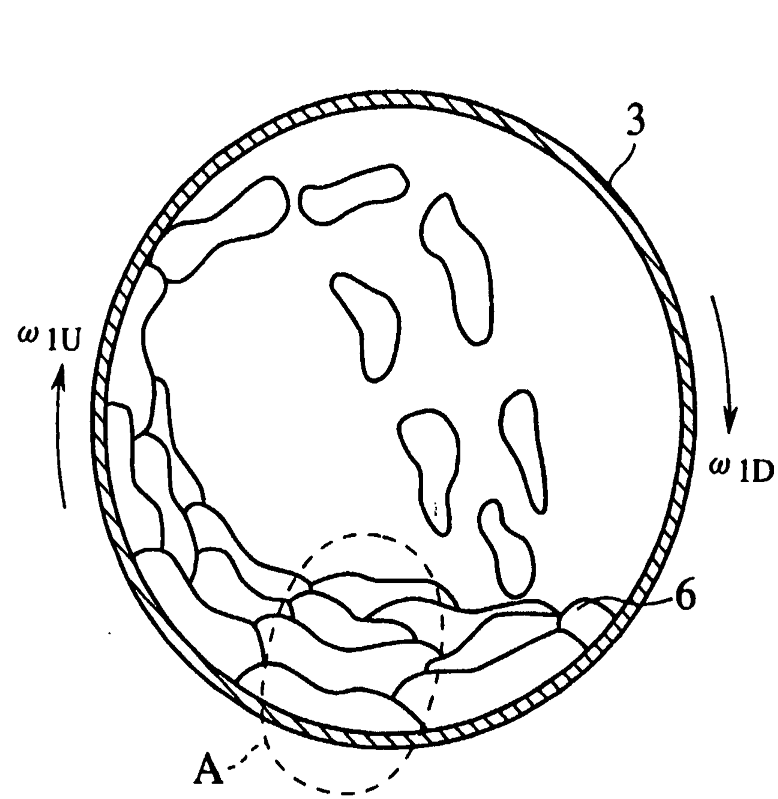
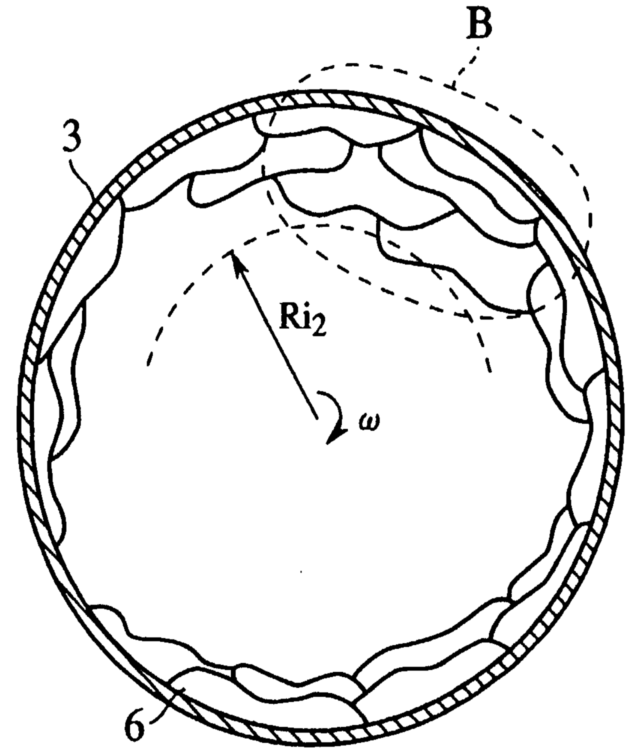


FIG.11B
PRIOR ART



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FRONT-LOADING WASHING MACHINE

The present invention relates to a front-loading washing machine, and particularly, to a technique of balancing laundry in the washing machine during the spin-drying of the laundry.

Figure 8 shows an example of a front-loading washing machine according to a prior art. The washing machine has a casing 1 and a water tank 2. The tank 2 is supported by a suspension 4 and incorporates a washing-and-spin-drying drum 3. The drum 3 is rotatably supported by a horizontal shaft. A motor 5 is arranged under the tank 2. The rotation of the motor 5 is transmitted to the drum 3 through pulleys (not shown) and a belt (not shown).

When spin-drying laundry 6, the motor 5 drives the drum 3 at a given spin-drying speed N0 so that centrifugal force may press the laundry 6 against the circumferential inner wall of the drum 3. At this time, the laundry 6 is unevenly distributed over the inner wall of the drum 3 to fluctuate centrifugal force. This results in vibrating the tank 2 and thus the washing machine itself through the suspension 4, etc.

The front-loading washing machine turns the drum 3 around the horizontal shaft that extends in parallel with the floor 7. When the laundry 6 has an imbalance in its distribution on the drum 3 during spin-drying, the tank 2 vibrates in a plane that is perpendicular to the floor 7, to vibrate the floor 7. The vibration of the floor 7 caused by the front-loading washing machine is severer than

that caused by a top-loading washing machine that turns a drum around a vertical shaft. It is sometimes necessary, therefore, to reinforce the floor under the front-loading washing machine. The vibration may be suppressed by increasing the weight of the front-loading washing machine, but this increases the size thereof.

Most effective means to reduce the vibration of the front-loading washing machine is to evenly distribute the laundry 6 over the inner wall of the drum 3 before driving the drum 3 at the spin-drying speed N0. A technique of achieving this idea is disclosed in Japanese Unexamined Patent Publication No. 54-18163. This disclosure will be explained with reference to Figs. 8 to 11. When the drum 3 is stopped, the laundry 6 is at the bottom of the drum 3 as shown in Fig. 9. If the drum 3 is rotated up to the spin-drying speed N0 under this state, the laundry 6 is kept biased to have a large distribution imbalance.

To evenly distribute the laundry 6 on the drum 3, the disclosure carries out an equalizing process before spin-drying the laundry 6, as shown in Fig. 10.

At first, the laundry 6 is disentangled by repeating turning the drum 3 in a normal direction at about 50 rpm, stopping the same, and turning it in a reverse direction at about 50 rpm. Thereafter, the drum 3 is driven at a revolution speed NP at which centrifugal acceleration (= $R \cdot \omega^2$) is substantially equal to gravity, for a predetermined period. Then, the drum 3 is driven at the spin-drying speed N0. In this way, the prior art tries to minimize the distribution imbalance of the laundry 6 before the drum 3 reaches the spin-drying speed N0.

This prior art starts to drive the drum 3 at the speed NP with the laundry 6 settled at the bottom of the drum 3. Accordingly, there is a large difference in load on the motor 5 between turning the laundry 6 upward and turning the same downward. Namely, an upward angular velocity ω 1U of the drum 3 is lower than a downward angular velocity

ω 1D thereof (ω 1U < ω < ω 1D). In other words, upward centrifugal acceleration is smaller than gravity. Part of the laundry 6 of Fig. 9 close to the center of the drum 3 receives small centrifugal acceleration and only rotates around the bottom of the drum 3 without being lifted upward.

Then, even if the drum 3 is driven at NP where centrifugal acceleration balances with gravity, the laundry 6 is not pressed against the inner wall of the drum 3, as shown in Fig. 11A, and when the drum 3 is driven at the spin-drying speed N0, the laundry 6 may have a distribution imbalance A. To evenly distribute the laundry 6, which is at the bottom of the drum 3 when the drum 3 is started, the revolution speed NP must sufficiently be large to produce centrifugal acceleration that is greater than gravity. In this case, centrifugal acceleration balances with gravity at a radius Ri2 ($Ri2 \cdot \omega^2 = g$) as shown in Fig. 11B. Then, some pieces of the laundry 6 farther than the radium Ri2 are pressed against the drum 3, and the laundry 6 has a distribution imbalance B.

An object of the present invention is to provide a front-loading washing machine capable of evenly distributing laundry over the circumferential inner wall of a washing-and-spin-drying drum before driving the drum to a predetermined spin-drying speed, to thereby spin-dry the laundry without severe vibration.

In order to accomplish the object, an aspect of the present invention provides a front-loading washing machine having a control circuit that increases, in a spin-drying operation, the revolution speed of a washing-and-spin-drying drum in steps up to a predetermined spin-drying speed, in which the steps include one whose revolution speed is lower than that of the preceding step. Even if

laundry pressed against the circumferential inner wall of the drum has a distribution imbalance, the lower-speed step repeatedly drops the imbalanced part of the laundry from the top to the bottom of the drum as the drum rotates. This cancels the imbalanced part of the laundry and evenly distributes the laundry over the inner wall of the drum before the drum reaches the spin-drying speed.

The control circuit may control the revolution speed of the drum to satisfy CF1 > 1G, and CF2 ≦ 1G, where CF1 is centrifugal force at an average radius of the laundry pressed against the drum in the step that precedes the lower-speed step and whose revolution speed is N1, CF2 is centrifugal force at an average radius of the laundry pressed against the drum in the lower-speed step whose revolution speed is N2, and G is the gravitational constant. When the drum is turned at N1, the laundry is pressed against the drum. If the laundry has a distribution imbalance at this time, the imbalanced part thereof repeatedly drops from the top to the bottom of the drum due to gravity when the drum speed is lowered to N2. As a result, the imbalanced part of the laundry is canceled, and the laundry is evenly distributed over the inner wall of the drum.

The control circuit may determine the revolution speeds N1 and N2 of the drum based on the quantity of the laundry. An inner radius of the laundry when it is evenly distributed on the drum is dependent on the quantity of the laundry. If the quantity is large, the inner radius thereof is small, and if the quantity is small, the inner radius is large. Accordingly, if the quantity of the laundry is large, the revolution speeds N1 and N2 of the drum are increased so that the laundry may balance with gravity at the inner radius. If the quantity of the laundry is small, the revolution speeds N1 and N2 are reduced accordingly. This technique stably cancels an imbalance in the distribution of laundry.

The control circuit may determine the revolution speeds N1 and N2 of the drum based on the properties of laundry. An inner radius of the laundry when it is evenly distributed on the drum is dependent on the properties of the laundry. The harder the laundry, the smaller the inner radius, and softer the laundry, the larger the inner radius. If the laundry is hard, the control circuit increases the revolution speeds N1 and N2 of the drum, and if the laundry is soft, decreases the revolution speeds N1 and N2 of the drum, so that the laundry may stably balance with gravity at the inner radius.

The control circuit may detect an imbalance in the distribution of laundry in the drum according to the load torque of a motor while the motor is driving the drum at the revolution speed N2 that is slower than N1. Any distribution imbalance of the laundry fluctuates the revolutions of the drum and thus the load torque of the motor. It is possible, therefore, to surely detect a distribution imbalance of the laundry according to the load torque of the motor.

The control circuit may detect an imbalance in the distribution of laundry in the drum according to the difference between the load torque of the motor at the revolution speed N1 and that at the revolution speed N2. If the laundry has a distribution imbalance, the load torque of the motor at N2 will be greater than that at N1 because the laundry drops from the top to the bottom of the drum at N2. It is possible, therefore, to surely detect the scale of a distribution imbalance according to the load torque difference of the motor between the revolution speeds N1 and N2.

The control circuit may alternate the revolution speed of the drum between N1 and N2 until a distribution imbalance of laundry is suppressed below a predetermined level.

If the distribution imbalance of laundry does not drop

below the predetermined level, the control circuit may increase the revolution speeds N1 and N2 of the drum by a predetermined value and decrease the spin-drying speed N0 of the drum by a predetermined value. Increasing N1 and N2 decreases the inner radius of laundry where the laundry balances with gravity and strongly presses the laundry against the inner wall of the drum. Decreasing the spin-drying speed N0 suppresses vibration and maintains the balanced state of the laundry.

These and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings, in which:

Fig. 1 shows the internal structure of a front-loading washing machine according to an embodiment of the present invention;

Fig. 2 is a block diagram showing a control circuit of the washing machine of Fig. 1;

Fig. 3 is a time chart showing a spin-drying operation of the washing machine of Fig. 1;

Figs. 4A and 4B show the states of laundry in the washing machine of Fig. 1 at revolution speeds N1 and N2;

Fig. 5 shows an ideal state of laundry that is evenly distributed on the inner wall of a drum of the washing machine of Fig. 1;

Figs. 6A and 6B show the states of laundry involving a large distribution imbalance at the revolution speeds N1 and N2 in the washing machine of Fig. 1;

Fig. 7 is a flowchart showing the steps of controlling a spin-drying operation of the washing machine of Fig. 1;

Fig. 8 shows the internal structure of a front-loading washing machine according to a prior art;

Fig. 9 shows the state of laundry in a drum that is stopped in the washing machine of Fig. 8;

Fig. 10 is a time chart showing a spin-drying operation of the washing machine of Fig. 8; and

Figs. 11A and 11B show the spin-drying states of laundry in the drum of the washing machine of Fig. 8.

Preferred embodiments of the present invention will be explained with reference to Figs. 1 to 7.

Figure 1 shows a front-loading washing machine according to an embodiment of the present invention. In this drawing, the same parts as those of the prior art of Fig. 8 are represented with like reference marks and are not explained again.

A casing 1 accommodates a washing-and-spin-drying drum 3 and a control circuit 10. The control circuit 10 is arranged at lower part of the casing 1, to control the revolution speed of the drum 3, etc. A motor 5 for driving the drum 3 has a revolution speed sensor (not shown) for detecting the number of revolutions of an output shaft of the motor 5. At the top of the casing 1, there are arranged a key unit (not shown) for entering instructions, an indicator, etc.

Figure 2 is a block diagram showing a control system of the washing machine of Fig. 1. The control system includes the control circuit 10, the motor 5, a drive circuit 18 for driving the motor 5, the indicator 19, etc. The control circuit 10 incorporates an operation unit 11, a memory 12, a controller 13, and a counter 14.

The control circuit 10 receives signals 15 from keys and switches, a motor speed signal 16, a motor load current signal 17, etc. The control circuit 10 controls the motor 5 through the drive circuit 18, as well as the display operation of the indicator 19.

Control methods (1) to (7) carried out by the control circuit 10 will be explained.

(1) Driving the drum 3 at revolution speeds N1 and N2 (N1 > N2) that are slower than a predetermined spin-drying speed N0

In Fig. 3, the control circuit 10 drives the drum 3 at 50 rpm in a normal direction, stops it, drives it at 50 rpm in a reverse direction, and stops it. The control circuit 10 repeats these operations to disentangle the laundry 6. Thereafter, the control circuit 10 drives the drum 3 at N1 to press the laundry 6 against the circumferential inner wall of the drum 3. Just before driving the drum 3 at N1, the drum 3 is stopped, and therefore, the laundry 6 is at the bottom of the drum 3. Accordingly, N1 is set to make centrifugal force applied to the laundry 6 sufficiently larger than gravity. The laundry 6 has a distribution imbalance C as indicated with a dotted line in Fig. 4A when the drum 3 is driven at N1. The control circuit 10 drives the drum 3 at N1 for a predetermined period of, for example, 20 sec to 30 sec so that the peripheral part of the laundry 6 is pressed hard against the inner wall of the drum 3.

Then, the control circuit 10 drops the revolution speed of the drum 3 from N1 to N2 at which centrifugal force at a theoretical inner radius Ri of the laundry 6 balances with gravity ($Ri \cdot \omega^2 = g$). Here, the theoretical inner radius Ri is a radius that is taken by the laundry 6 when the laundry 6 is ideally uniformly distributed over the inner wall of the drum 3. In other words, if the laundry 6 is ideally distributed on the drum 3 when the drum 3 is driven at N2, the laundry 6 will stably maintain the state. If the laundry 6 has a distribution imbalance when the drum 3 is driven at N2, part of the laundry 6 farther than the theoretical inner radius Ri is kept pressed against the inner wall of the drum 3, and part of the laundry 6 having a rotation radius Ra that is shorter

than Ri is pulled by gravity and drops to the bottom of the drum 3 when the part is lifted to the upper part of the drum 3. In this way, at the revolution speed N2, the distribution imbalance C of the laundry 6 is repeatedly dropped from the top to the bottom of the drum 3. As a result, the distribution imbalance C of the laundry 6 is canceled, and the laundry 6 is fully contained in the theoretical inner radius Ri. Namely, the laundry 6 is evenly distributed on the inner wall of the drum 3.

The drum 3 is turned at the speed N2 for a predetermined period of, for example, 20 sec to 30 sec, and is driven at the predetermined spin-drying speed N0. The revolution speeds N1 and N2 of the drum 3 are, for example, N1 > 80 rpm, N2 < 80 rpm, CF1 > 1G, and CF2 ≦ 1G, where G is the gravitational constant, CF1 is centrifugal force at N1, and CF2 is centrifugal force at N2. For example, the drum 3 has a diameter of 480 mm and the laundry 6 weighs 3 kg. In this case, N1 is about 100 rpm and N2 is about 72 rpm.

This control method cancels a distribution imbalance of the laundry 6 before the drum 3 reaches the spin-drying speed N0, thereby preventing the drum 3 from vibrating.

(2) Determining the revolution speeds N1 and N2 of the drum 3 according to the quantity of the laundry 6

The quantity of the laundry 6 is detectable from, for example, the load torque of the motor 5 at the start of the motor 5. The quantity of the laundry 6 determines the theoretical inner radius Ri of the laundry 6 for equally distributing the laundry 6 over the inner wall of the drum 3. If the quantity of the laundry 6 is large, Ri is small, and if it is small, Ri is large. The control circuit 10 detects the quantity of the laundry 6 before the spin-drying operation. According to the detected laundry quantity, the control circuit 10 determines the revolution speeds N1 and N2 of the drum 3. If the laundry quantity is

large, N1 and N2 are increased, and if the laundry quantity is small, N1 and N2 are decreased, to always balance the laundry 6 with gravity at the theoretical inner radius Ri.

In this way, this control method controls the revolution speeds N1 and N2 of the drum 3 according to the quantity of the laundry 6, to cancel an imbalance in the distribution of the laundry 6 in the drum 3.

(3) Determining the revolution speeds N1 and N2 of the drum 3 according to the properties of the laundry 6

The properties of the laundry 6 are detectable according to, for example, a change in the load torque of the motor 5. Even if the quantity of the laundry 6 is unchanged, the theoretical inner radius Ri of the laundry 6 for evenly distributing the laundry 6 over the inner wall of the drum 3 differs depending on the properties of the laundry 6. The harder the laundry 6, the smaller the theoretical inner radius Ri, and the softer the laundry 6, the larger the theoretical inner radius Ri. The control circuit 10 detects the properties of the laundry 6 before the drum 3 reaches the spin-drying speed N0. According to the detected properties of the laundry 6, the control circuit 10 determines the revolution speeds N1 and N2 of the drum 3. If the laundry 6 is hard, the control circuit 10 increases N1 and N2, and if the laundry 6 is soft, decreases N1 and N2, to always balance the laundry 6 with gravity at the theoretical inner radius Ri.

In this way, this control method controls the revolution speeds N1 and N2 of the drum 3 according to the properties of the laundry 6, to cancel an imbalance in the distribution of the laundry 6 in the drum 3.

(4) Detecting an imbalance in the distribution of the laundry 6 in the drum 3 according to the load torque of the motor 5 at the revolution speed N2

The revolution speed sensor detects the revolution

speed of the motor 5, and the operation unit 11 calculates a temporal change in the output of the revolution speed sensor and calculates the load torque of the motor 5. In Fig. 3, the drum 3 is driven at the revolution speeds N1 and N2 before it is driven at the spin-drying speed N0. If the laundry 6 involves a large imbalance in the distribution thereof as shown in Fig. 6A when the drum 3 is driven at N2, the load torque of the motor 5 differs between when the imbalanced part of the laundry 6 is lifted upward and when the same is descended. As a result, the drum 3 is slowed down when the imbalanced part is lifted and is sped up when the imbalanced part is descended, due to the inertia of the imbalanced part and gravity. In this way, the revolution speed of the drum 3 fluctuates in each cycle. This results in dropping not only the imbalanced part of the laundry 6 but also other parts thereof pressed against the drum 3 from the top to the bottom of the drum 3 as shown in Fig. 6B.

There is a difference in the load torque or revolution speed of the motor 5 between the large imbalance state of Fig. 6B and the small imbalance state of Fig. 4B. The large imbalance state of Fig. 6B greatly fluctuates the revolution speed of the motor 5. The control circuit 10 detects a fluctuation in the revolution speed of the motor 5 at N2. If the fluctuation is greater than a predetermined level to indicate a distribution imbalance of the laundry 6, the control circuit 10 does not increase the drum 3 to the spin-drying speed N0. Instead, the control circuit 10 again drives the drum 3 at N1 and N2 and detects a fluctuation in the revolution speed of the motor 5. The control circuit 10 repeats these processes until no fluctuation is detected in the revolution speed of the motor 5 at N2 and then increases the drum 3 to the spin-drying speed N0.

In this way, this control method surely detects an imbalance in the distribution of the laundry 6 in the drum

3 and cancels the imbalance.

(5) Detecting an imbalance in the distribution of the laundry 6 in the drum 3 according to a difference in the load torque of the motor 5 between the revolution speeds N1 and N2

The operation unit 11 calculates temporal fluctuations in the revolution speed of the motor 5 when the drum 3 is driven at N1 and N2, stores the calculation results in the memory 12, and finds out the difference between them. A fluctuation in the revolution speed of the motor 5 at N1 is δ 1, and that at N2 is δ 2. If δ 2 > δ 1, there is an imbalance in the distribution of the laundry 6 with the drum 3 being driven at N2, as explained in the control method (4). Accordingly, if the difference between δ 1 and δ 2 is greater than a predetermined level, the control circuit 10 does not increase the drum 3 to the spin-drying speed N0. Instead, the control circuit 10 again drives the drum 3 at N1 and N2 and detects the fluctuation difference between N1 and N2. The control circuit 10 repeats these processes until the fluctuation difference becomes below the predetermined level and then increases the drum 3 to the spin-drying speed N0.

In this way, this control method surely detects an imbalance in the distribution of the laundry 6 in the drum 3 without information about the quantity or properties of the laundry 6 and cancels the imbalance.

(6) Detecting fluctuations in the revolution speed of the motor 5 according to fluctuations in the load torque of the motor 5

The revolution speed sensor detects the revolution speed of the motor 5, and the control circuit 10 controls a voltage to the motor 5 so that the motor 5 may keep a given speed. According to a change in the voltage to the motor 5, the operation unit 11 calculates a temporal fluctuation

in the load torque of the motor 5, i.e., a fluctuation in the revolution speed of the motor 5.

Then, this control method detects an imbalance in the distribution of the laundry 6 in the drum 3 and cancels the imbalance similar to the control methods (4) and (5).

(7) Alternating the revolution speed of the drum 3 between N1 and N2 until an imbalance in the distribution of the laundry 6 in the drum 3 is suppressed below a predetermined level, and if the imbalance is not suppressed thereby, increasing N1 and N2 and decreasing the spin-drying speed N0

This control method will be explained with reference to the flowchart of Fig. 7. Step 101 drives the drum 3 at N1 as shown in Fig. 3. Step 102 decreases the drum speed from N1 to N2. Under this state, step 103 determines whether or not there is an imbalance in the distribution of the laundry 6 in the drum 3 according to one of the control methods (4) and (5). If there is a large imbalance, steps 101 to 103 are repeated. Step 104 determines whether or not the number of repetitions of steps 101 to 103 is below a predetermined value. If step 104 determines that the number of repetitions is greater than the predetermined value, step 106 supplies water into the drum 3 to disentangle the laundry 6, step 107 several times repeats driving the drum 3 at 50 rpm in a normal direction, stopping the drum 3, and driving the drum 3 at 50 rpm in a reverse direction, and step 108 discharges water. Then, steps 101 to 103 are repeated for the predetermined times. If step 104 determines, for the second time, that the number of repetitions of steps 101 to 103 is greater than the predetermined value, step 110 increases the values N1 and N2 to reduce the inner radius of the laundry 6 at which the laundry balances with gravity, thereby extending the allowable range of imbalance. At the same time, step 110 reduces the spin-drying speed N0. Step 111 drives the drum

3 at the increased speed N1, and step 112 drives the drum 3 at the increased speed N2. Step 113 spin-dries the laundry 6 at the decreased spin-drying speed N0, to complete the spin-drying of the laundry 6.

If step 103 detects that the distribution imbalance of the laundry 6 is small, no change is made in N1, N2, and N0, and step 114 spin-dries the laundry 6 at the normal spin-drying speed N0, to complete the spin-drying of the laundry 6.

In this way, this control method detects an imbalance in the distribution of the laundry 6, repeats imbalance reducing processes if the imbalance is large, and if it is difficult to reduce the imbalance, increases the revolution speeds N1 and N2 of the drum 3 and reduces the spin-drying speed N0, to completely spin-dry the laundry 6 without vibrating the drum 3.

In summary, the present invention provides a front-loading washing machine having a control circuit that increases, in a spin-drying operation, the revolution speed of a washing-and-spin-drying drum in steps up to a predetermined spin-drying speed, in which the steps include one whose revolution speed is lower than that of the preceding step. This arrangement cancels an imbalance in the distribution of laundry, evenly distributes the laundry over the circumferential inner wall of the drum before the drum is driven to the spin-drying speed, and thereby reduces vibration in the spin-drying operation.

The control circuit may control the revolution speed of the drum to satisfy CF1 > 1G, and CF2 ≦ 1G, where CF1 is centrifugal force at an average radius of the laundry pressed against the drum in the step that precedes the lower-speed step and whose revolution speed is N1, CF2 is centrifugal force at an average radius of the laundry pressed against the drum in the lower-speed step whose revolution speed is N2, and G is the gravitational constant. This arrangement cancels an imbalance in the

distribution of laundry, evenly distributes the laundry over the inner wall of the drum before the drum is driven to the spin-drying speed, and thereby surely reduces vibration in the spin-drying operation.

The control circuit may determine the revolution speeds N1 and N2 of the drum based on the quantity of the laundry. This arrangement stably cancels an imbalance in the distribution of laundry irrespective of the quantity of the laundry.

The control circuit may determine the revolution speeds N1 and N2 of the drum based on the properties of the laundry. This arrangement stably cancels an imbalance in the distribution of laundry irrespective of the properties of the laundry.

The control circuit may detect an imbalance in the distribution of laundry in the drum according to the load torque of a motor while the motor is driving the drum at the revolution speed N2 that is slower than N1. Any distribution imbalance of the laundry fluctuates the revolutions of the drum and thus the load torque of the motor. It is possible, therefore, to surely detect an imbalance in the laundry distribution according to the load torque of the motor.

The control circuit may detect an imbalance in the distribution of laundry in the drum according to the difference between the load torque of the motor at the revolution speed N1 and that at the revolution speed N2. If the laundry has a distribution imbalance, the load torque of the motor at N2 will be greater than that at N1 because the laundry drops from the top to the bottom of the drum at N2. It is possible, therefore, to surely detect the scale of a distribution imbalance of the laundry according to the load torque difference of the motor between the revolution speeds N1 and N2.

The control circuit may alternate the revolution speed of the drum between N1 and N2 until a distribution

imbalance of laundry is suppressed below a predetermined level. This arrangement more evenly distributes the laundry over the drum and further reduces vibration.

If the distribution imbalance of laundry does not drop below the predetermined level, the control circuit may increase the revolution speeds N1 and N2 of the drum by a predetermined value and decrease the spin-drying speed N0 by a predetermined value. This arrangement surely cancels the distribution imbalance of laundry and greatly reduces vibration in the spin-drying operation.

While the above provides a full and complete disclosure of the preferred embodiments of the present invention, various modifications, alternate constructions, and equivalents may be employed without departing from the scope of the invention. Therefore, the above description and illustration should not be construed as limiting the scope of the invention, which is defined by the appended claims.

CLAIMS:

1. A front-loading washing machine comprising:

control means that increases, in a spin-drying operation, the revolution speed of a washing-and-spin-drying drum in steps up to a predetermined spin-drying speed, in which the steps include one whose revolution speed is lower than that of the preceding step.

2. A washing machine according to Claim 1, wherein said control means controls the revolution speed of the drum to satisfy CF1 > 1G, and CF2 ≤ 1G, where CF1 is centrifugal force at an average radius of the laundry pressed against the drum in the step that precedes the lower-speed step and whose revolution speed is N1, CF2 is centrifugal force at an average radius of the laundry pressed against the drum in the lower-speed step whose revolution speed is N2, and G is the gravitational constant.

3. A washing machine according to Claim 1 or Claim 2, wherein said control means determines the revolution speeds N1 and N2 of the drum based on the quantity of the laundry.

4. A washing machine according to Claim 3, wherein said control means determines the quantity of the laundry according to the load torque of a motor that drives the drum.

5. A washing machine according to Claim 1 or Claim 2, wherein said control means determines the revolution speeds N1 and N2 of the drum based on the properties of the laundry.

6. A washing machine according to Claim 5, wherein said control means determines the properties of the laundry according to a fluctuation in the load torque of a motor that drives the drum.

7. A washing machine according to Claim 1 or Claim 2, wherein said control means detects an imbalance in the distribution of the laundry in the drum according to the load torque of a motor while the motor is driving the drum at the revolution speed N2 that is slower than N1.

8. A washing machine according to Claim 1 or Claim 2, wherein said control means detects an imbalance in the distribution of the laundry in the drum according to the difference between the load torque of the motor at the revolution speed N1 and that at the revolution speed N2.

9. A washing machine according to Claim 7 or Claim 8, wherein said control means alternates the revolution speed of the drum between N1 and N2 until the distribution imbalance of the laundry is suppressed below a predetermined level.

10. A washing machine according to Claim 9, wherein said control means increases the revolution speeds N1 and N2 of the drum by a predetermined value and decreases the spin-drying speed N0 by a predetermined value, if the distribution imbalance of the laundry does not drop below the predetermined level.

11. A washing machine substantially as described herein with reference to the accompanying drawings.

Application No:	GB 9802918.4	**Examiner:**	R L Williams
Claims searched:	1-11	**Date of search:**	4 March 1998

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Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): D1A (ACA)(ACB)(ACD)(ADNX)

Int Cl (Ed.6): D06F 33/02,35/00,37/20

Other: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	EP 0,732,437 A1	Merloni Elettrodomestici S.p.A.	1
X	EP 0,704,567 A1	Electrolux Zanussi Elettrodomestici S.p.A.	1
X	US 4,856,301	J Broadbent	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

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